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TEACHING MULTIPLICATION FACTS TO STUDENTS WITH LEARNING DISABILITIES

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Multiple baseline designs were used to examine the effects of an instructional package on accuracy of performance in solving multiplication facts by 3 students with learning disabilities. The instructional package included the following components: (a) a modified instructional sequence in which multiplication facts were grouped into the zeros, ones, doubles, fives, and nines categories, and those remaining; (b) identification of the category in which each fact belonged; (c) mnemonic strategies associated with solving facts in each category; and (d) steps to be completed for solving facts in each category. Results indicated that the instructional package produced substantial and immediate effects. After receiving instruction, a participant's accuracy was often 100%, and this was maintained throughout the evaluation even as other strategies were introduced. Comparable results occurred across students, demonstrating replication of the effects of the instructional package.

DESCRIPTORS: instructional strategies, mnemonic strategies, self-instruction, multiplication facts, learning disabilities

Many students with learning disabilities experience difficulties in learning mathematics (Cawley & Miller, 1989), yet very little applied research has been conducted on the instructional needs of these students. Consequently, teachers often select instructional interventions for students who exhibit mathematics difficulties with no systematic effort to link the intervention procedures to specific deficits. Students with learning disabilities who experience difficulties in mathematics are frequently taught multiplication facts using the same procedures and sequences that are used with students without difficulties, that is, repetition drills (Greene, 1992). An alternative approach is to employ instructional strategies based on theory or empirical analysis. Modifying both the sequence of instruction and the instructional strategies within that sequence may facilitate mastery of multiplication facts (Thornton & Toohey, 1985).

McComas and her colleagues (McComas, Wacker, & Cooper, 1996; McComas, Wacker, Cooper, et al., 1996) demonstrated, for example, that matching individualized instructional strategies to specific students with learning problems resulted in immediate improvement in academic performance across academic areas in both classroom and outpatient clinic settings. However, these investigators did not use a conceptual or hierarchical approach to selecting instructional strategies, meaning that strategies were applied to individual students in a trial-and-error fashion. A more efficient approach may be to evaluate strategies that are matched specifically to individuals or subgroups of students with identified learning problems.

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Miller and Mercer (1993) found that students who experience difficulties in math may perform poorly in basic fact memorization or completion of a variety of mathematical problems. One instructional strategy that has shown potential for improving rote memory is teaching students to use mnemonics. Mastropieri and Scruggs (1991) defined a mnemonic as "a device, procedure, or operation that is used to improve memory" (p. 271). Numerous studies have validated the benefits of mnemonic instruction (Mastropieri, 1983; Mastropieri & Scruggs, 1989; Pressley, Levin, & Delaney, 1982; Scruggs & Mastropieri, 1989; Veit, Scruggs, & Mastropieri, 1986). In these studies, mnemonic instruction was shown to produce results that were positive and consistent.

In operant terms, instruction of mnemonics might be considered as a mediational stimulus generalization procedure (Stokes & Baer, 1977), comparable in both form and function to self-instruction (Karlan & Rusch, 1982). In the case of mathematics instruction, the student is taught one set of behaviors that mediates or facilitates displays of desired responding. For example, McComas, Wacker, and Cooper (1996) taught students who were experiencing difficulty with reading comprehension to summarize key ideas in a passage by using a checklist to guide their writing of a summary that included the main idea, major action of characters, and setting of the passage.

In this study, we evaluated an instructional package that was designed to teach the following behaviors: (a) Participants were taught to ask themselves a specific question regarding the form of each multiplication fact appearing on a probe (i.e., "Does the problem have a 0, 1, 2, 5, or 9?"); (b) if the answer was yes, participants were taught a strategy involving a specific set of steps for solving the problem (e.g., "Yes, it has a 0. So the answer is 0."); (c) if the answer was no, participants were taught mnemonics designed to help them remember the answer associated with the multiplication fact; and (d) after being shown their score on a multiplication facts probe, participants were encouraged to attribute correct responses to their use of the strategies taught.

The evaluation of the instructional package was conducted with individual participants using a multiple baseline design across multiplication fact categories. Three children participated. We conducted training within a multiple baseline to determine whether practice affected learning and to identify whether instruction on one category of facts generalized to other categories of facts. We predicted that generalization would not occur because a given strategy was unique to each set of multiplication facts.

METHOD

Setting and Participants

The 3 participants in this study attended special education programs for children with learning disabilities. These programs were located in a large, multiracial, multiethnic, and socioeconomically diverse urban school district that served approximately 17,000 students, of which about one fourth were children of color and about one third were from families of lower socioeconomic status (SES; determined by student qualification for the free or cost-reduced school lunch program). Each had experienced difficulties in acquiring basic multiplication facts at school that were assumed by local educational diagnostic teams to be related to identified memory deficits. Two of the participants (Tom and Craig) were in regular education classes for math for third grade when basic multiplication facts were taught. The school district math curriculum guide, followed by their teachers, was typical in the sequence of introducing the multiplication facts. The 3rd participant (Damien) was a fifth grader who had not acquired multiplication facts in the fourth grade (as documented in his individualized education program; IEP).

Tom

Tom, a fourth grader, was a 10-year-old Caucasian boy from a family with lower SES. He remained in a regular classroom for most of the school day, coming to the special education teacher for small-group mathematics instruction. Tom's full-scale IQ on the Wechsler Intelligence Scale for Children—III (WISC-III) was 87. On the Woodcock-Johnson Psychoeducational Battery Achievement Tests–Math section, Tom had a grade equivalent score of 2.3 for computation and problem-solving skills. His permanent school record contained a report from a school psychologist indicating low rote-memorization skills; this conclusion was based upon an interpretation of Tom's performance on the WISC-III. He demonstrated little knowledge of multiplication facts during baseline testing in the present investigation.

Craig

Craig, a fourth grader, was a 10-year-old Caucasian boy from a family with lower SES. He was identified as qualifying for special education services for math instruction at the end of his third-grade school year. Craig's full-scale IQ (WISC-III) was 90. On the Woodcock-Johnson Psychoeducational Battery Achievement Tests–Math section, he had a grade equivalent score of 1.6 for computation and problem-solving skills. He began receiving instruction in a regular classroom at the beginning of his fourth-grade school year but was unable to make progress in math in that setting. Therefore, he received small-group math instruction in the special education classroom. His permanent school record contained a report from a school psychologist indicating a short-term memory problem and difficulties in focusing and sustaining attention; this conclusion was based on an interpretation of Craig's performance on the WISC-III. Craig demonstrated little knowledge of multiplication facts during baseline testing in the present investigation.

Damien

Damien, a fifth grader, was a 10-year-old African-American boy from a family with lower SES. He was identified in first grade as qualifying for special education services. Damien's full-scale IQ (WISC-III) was 80. On the Woodcock-Johnson Psychoeducational Battery Achievement Tests–Math section, Damien had a grade equivalent score of 2.0 for computation and problem-solving skills. His permanent school record contained a report from a school psychologist indicating that he had memory deficits; this conclusion was based on an interpretation of his performance on the WISC-III. He had received instruction for 2 consecutive years in multiplication facts. His last IEP revealed that he had obtained 30% mastery of basic multiplication facts by the end of fourth grade.

For this study, each participant received small-group math instruction (4 to 6 students each) at a different time of the day in a special education classroom from a special education teacher who regularly provided their instruction. Damien received instruction in the morning, Tom at noon, and Craig in the afternoon. The sessions, lasting from 30 to 45 min per day, were structured so that none of the participants was present in the classroom when another received math instruction. Each participant in this investigation was selected because he had the lowest baseline performance among all students in his group.

Components of Instructional Package

An instructional package was developed, incorporating the five components described below.

Component 1: Modified Instructional Sequence

A modified instructional sequence was used in which facts involving the numerals zero and one were taught first, followed by the facts involving the numerals two, five, and nine. The remaining 15 facts were taught last in the instructional sequence because a simple series of steps for solving these problems was not available.

Component 2: Associative Learning

All 100 facts were classified into six categories: the zeros, ones, doubles (twos), fives, nines, and pegword (the remaining 15) facts. The instructional procedure involved associating each multiplication problem with its category. For example, participants were taught to associate the multiplication fact, 2×2, with the doubles category.

Component 3: Mnemonic Procedures

Zeros and ones needed no mnemonic procedures. A visual mnemonic flash card procedure adapted from Greene (1992) for doubles became part of the instructional package. Counting by fives was the mnemonic procedure for the facts in the fives category. A linking strategy adapted from Schroeder and Washington (1989) was incorporated as the mnemonic procedure for facts in the nines category. A pegword mnemonic procedure was adapted from Mastropieri and Scruggs (1991) and Willot (1982) for instruction in the facts in the pegword category.

Component 4: Strategic Learning

A strategy involving a few simple steps was developed to guide the participants in solving multiplication facts in each category. Participants first were taught to say the steps involving facts in each category. The steps then were practiced by applying them to problems on flash cards, the chalkboard, or worksheets.

The zeros strategy was the first introduced, using a strategy chart with a few simple steps, and involved teaching participants to look for a 0 in the multiplication fact, then remembering that the answer would always be zero. The ones strategy was introduced using a strategy chart with a few simple steps, requiring participants to ignore the 1 in the multiplication fact and to instead write the other number as the answer.

The doubles strategy was introduced by first describing the step of doubling using real objects (a skateboard [two sets of two wheels], a six-pack of pop [two sets of three cans], a toy spider [two sets of four legs], two hands [two sets of five fingers], a carton of a dozen eggs [two sets of six eggs], a calendar [two sets of seven days makes two weeks], two toy octopi [two sets of eight legs], and an 18-wheeler toy truck [two sets of nine wheels]). Doubles flash cards, adapted from Greene (1992), were used to practice recognizing each set of doubles. When participants demonstrated acquisition (by responding correctly to all eight doubles flash cards two consecutive times), the doubles strategy chart was presented, and participants were taught to say the steps, first finding the 2 in the multiplication fact and then remembering a doubles picture related to the other number that would provide the answer to the problem.

Prior to introducing the fives strategy, counting by fives was reviewed. After the participants demonstrated acquisition (by correctly counting by fives to 100 two consecutive times), the fives strategy was introduced using a strategy chart with a few simple steps. These steps required participants first to identify the multiplication fact as a fives problem, then to count by fives to solve the problem.

The nines strategy involved first categorizing the multiplication fact as a nines problem and then using a linking procedure to find the answer. A strategy chart illustrating the linking procedure showed which numbers from 1 through 8 were linked as follows: 1 → 8, 2 → 7, 3 → 6, 4 → 5. Participants learned and practiced the links until they could immediately respond with the appropriate link when orally given a number by the teacher. In the multiplication fact 9 × 4, after classifying the problem as being in the nines category, participants subtracted 1 from the 4 and wrote the answer (i.e., 3) in the tens column under the problem, then put the link to this answer (i.e., 6) in the ones column under the problem. The nines strategy chart was then presented, and participants were taught to say the steps appearing on the chart. One session was dedicated to mastering the links, one session was dedicated to obtaining the tens place answer, and a third session was used to complete the ones place link for completion of the answer.

The pegword strategy required participants first to discriminate that a multiplication fact did not fit into any of the previous categories. Then, participants first associated the smaller number with a previously taught rhyming pegword (e.g., one–sun, two–shoe, three–tree, four–door), associated the larger number with the corresponding rhyming pegword, and finally remembered the picture that had previously been associated with these two pegwords, resulting in the answer. For example, in the problem 3 × 4, the pegwords were *tree* (rhymes with three) and *door* (rhymes with four); the picture representing this problem was a tree with a door in it and an elf (rhymes with 12, the answer) standing nearby. The fact that there were only 15 facts left to learn was stressed to the participants.

When pegword strategy instruction began, participants were shown a strategy chart and were taught to say the steps. The pegwords (e.g., one–sun) had been taught in previous lessons to allow the maximum amount of practice of the pegwords. Next, the first three pegword multiplication fact flash cards were presented, and elaborations were taught with the flash cards. For example, in the problem 3 × 6 = 18, participants were taught to say "tree and sticks are baiting." The elaboration was that trees like to have birds in their branches, so the tree is trying to catch a robin by baiting with a worm. When the participants saw the problem, they would say "tree" for 3, "sticks" for 6, and "tree and sticks are baiting." These facts and elaborations were adaptations of Mastropieri and Scruggs (1991).

After the first three problems were introduced with their elaborations, participants practiced following the steps on the pegword strategy chart to solve these problems. One or two subsequent facts were introduced sequentially across days.

Component 5: Self-Instruction Training

The teacher continually pointed out to the participants that they had the ability to categorize each problem (e.g., categorize 3 × 5 as being in the fives category), remember the appropriate strategy (e.g., "The problem has a 2 so I can use the doubles strategy"), execute the appropriate steps for a successful solution to the problem, and attribute success to appropriate strategy use. Students were taught to say to themselves while completing multiplication fact worksheets, "If I use the correct strategy, I will get this problem right." This component was designed to facilitate self-control (O'Leary & Dubey, 1979), thus fostering independence in computing multiplication facts following training.

Training Materials

Individual pegword flash cards were constructed on laminated posterboard (2.5 in. by 8 in.) (e.g., picture of a sun, picture of a shoe, etc.). Corresponding individual numeral cards (with only a numeral written on each) also were constructed on laminated posterboard. In addition, individual peg-

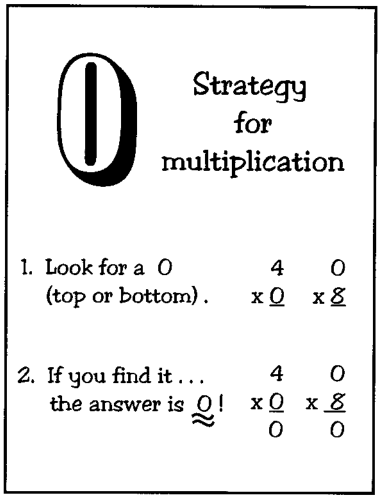

Figure 1. Example of a strategy chart.

word multiplication fact flash cards were illustrated on laminated posterboard (9 in. by 12 in.) (e.g., the $3 \times 3 = 9$ flash card contained an illustration of two trees [rhymes with three] on a line [rhymes with nine]). Further, a set of multiplication flash cards (multiplication facts only), sorted by strategies, was used to practice the six strategies after pegwords were learned. A strategy chart for each of the six strategies was illustrated on a laminated posterboard chart (11 in. by 14 in.) in various neon colors (see Figure 1 for example).

Multiplication Facts Test

The multiplication facts test consisted of five rows of six problems per row. Each row contained one multiplication fact from each of the six problem categories (zeros, ones, doubles, fives, nines, pegwords), resulting in five problems on the test representing each of the six categories. Ten different test forms, using randomly selected problems to represent the six categories, were constructed so that the position of each problem category in a row changed. For each test, six scoring templates were constructed so that problems related to each problem category could be quickly identified. Letters printed in the lower right corner (Z, O, D, F, N, P) allowed the problems to be classified according to category. For example, one of the scoring templates identified problems related to the zeros category.

The 10 test forms were numbered 1 to 10 and cycled in that order. As each test was being developed, flash cards with all 100 facts were separated into the six categories. One flash card from each category was randomly drawn for each row of problems and was set aside after use until all facts from that category had been used. Then facts from the "used-up" category were put back in the pile and randomly drawn again to ensure that all multiplication facts were encountered throughout the cycle of 10 tests.

Tests were scored by counting the number of problems answered correctly per problem category (e.g., number of problems involving zeros answered correctly) and recording this information in the lower right corner of the test. Scores then were transferred to individual participant graphs. The goal of this investigation was to improve accuracy of performance, which is a necessary step before fluency can be achieved.

Amount of Instructional Time Required

The zeros and ones strategies were taught, practiced, and tested on the same day because the participants acquired them quickly. All participants learned the steps for these strategies in 10 min or less. After the first session, new strategies were not introduced until a participant could attain three consecutive scores on the current strategy that were higher than their baseline scores. Instructional sessions were conducted once per day and ranged from 20 to 40 min in length. The doubles strategy took two instructional sessions, and the first test was administered at the end of the 2nd day. The fives strategy was easy to learn, because all 3 participants knew how to count by fives, so only one instructional session was needed, with the first test administered at the end of the instructional session. Three sessions were devoted to learning and practicing the nines strategy for all students, with the first test administered at the end of the third session. Approximately 3 weeks (about 15 sessions) of instruction were devoted to learning and practicing the pegword strategy.

Observation System and Interobserver Agreement

Multiplication Facts Tests

Interobserver agreement checks were conducted on the multiplication facts tests by the first author and a special education colleague trained in the data collection procedures used in this study. Agreement checks were conducted on score computations involving 33% of the multiplication facts tests administered to each participant (at least one check was conducted during baseline with each test involving each of the six strategies taught). Checks were conducted in the same manner regarding accurate transfer of results from test pages to participant graphs. An agreement was defined as both raters recording that the same problem was computed correctly or incorrectly. Interobserver agreement was computed by dividing the number of agreements by the number of agreements plus disagreements and then multiplying by 100%. No disagreements occurred for either computations or transfers.

Treatment Integrity

During the course of the study, the raters completed 10 probes to determine whether the multiplication test form used on a particular day contained five problems for each of the six categories of multiplication facts. Interobserver checks were conducted on seven (70%) of these probes. There was 100% agreement between raters that test forms contained the required number of problems for each category.

During the instructional sessions in which each of the six strategies was taught to a participant, an independent observer was present for one instructional session. Three older students from the same special education classroom as the participants served as the independent observers; thus, each participant had a different independent observer. Across the 3 participants, a total of 18 lessons were observed. Adult observers were not used in order to avoid potential problems caused by their presence in the classroom (e.g., distracting students). The peer observers had not experienced difficulties in learning mathematics. By selecting a different observer for each of the 3 participants, observers would not have heard the lesson for another group and could objectively determine whether each part of the lesson was taught. The independent observer and participant were involved in the lesson together. At the conclusion of a monitored session, the independent observer and participant were given identical observer checklists on which were listed 10 critical parts of the lesson. The independent observer and participant then independently marked the parts of the lesson they remembered observing. Checklists were not completed during a lesson so that participants and observers could devote their full attention to instruction.

Of the 18 lessons observed, both student observer and participant indicated on their checklists that all 10 critical parts had been included in each of 11 lessons (i.e., 100% agreement). Of the remaining seven lessons observed, the student observer and participant disagreed about the presence of one critical part (90% agreement). The mean interobserver agreement across the 18 lessons was 96%.

Experimental Design

Data were collected within a multiple baseline across behaviors (multiplication facts) design with replications across students to analyze the effects of each instructional strategy on each specific category of multiplication facts. This design was selected to answer the following questions: (a) Did instruction in a particular strategy result in immediate improvement for only specific multiplication facts, and (b) was performance maintained on previously trained multiplication facts as successive strategies were introduced?

Procedure

Baseline Testing

Baseline testing using the multiplication facts test was conducted for 3 consecutive days for each of the 3 participants. A different version of the test was administered each day. Participants were given as much time as needed and were instructed to answer all problems, even when they weren't sure of their answer. Three consecutive days of stable baseline data, during which a participant scored ≤40% correct on each of the six categories of multiplication facts, served as the criterion for progressing to instruction on the first strategy involving zeros. During baseline testing, consequences in the form of teacher praise were provided for completing the multiplication tests.

Introduction of Instructional Package

Participants were told that they were going to learn a new way to remember multiplication facts and that six strategies would teach them all 100 facts. Nearly every day they would be tested and reinforced for correctly answering the problems for which they had learned a strategy. Participants also were told that they would progress to the next strategy when their graph showed three scores in a row for the current strategy that were better than their baseline scores for the respective strategy.

General Lesson Procedure

Several procedures remained constant during all instruction. Each day, the following elements were presented: (a) pegword instruction, review, and practice; (b) strategy review and practice; and (c) feedback concerning the participant's performance.

Pegword instruction, review, and practice. Pegwords (e.g., one–sun) were taught and practiced daily because of the complexity of the pegword strategy. One to three of the pegwords were introduced daily, depending on the learning rate of the participant. All new and previously learned pegwords were practiced daily in two different ways: (a) presentation of the pegword cards by the teacher, followed by the participants saying the corresponding numbers; and (b) presentation of the number cards by the teacher, followed by the participants saying the corresponding pegword.

Strategy review and practice. Strategies that had been taught in previous lessons were reviewed and practiced as a part of each lesson. Although the steps of each previously taught strategy were reviewed in each subsequent lesson, practice with actual problems involved only the currently taught strategy. There was no practice of problems involving previously taught strategies. During each lesson, a combination of flash card games, chalkboard practice, and worksheet practice was used to review and practice the multiplication facts.

Feedback. During lessons, the special education teacher gave participants feedback concerning their performance and attributed success or had participants attribute success to their correct application of a strategy. When incorrect strategies were used, the teacher assisted the participants in attributing the error to the nonapplication or incorrect application of the correct strategy, then reviewed the correct strategy, and again practiced the strategy.

Monitoring Progress

When all members of a group demonstrated acquisition during practice with flash cards, board work, or practice worksheets (all members of the instructional group gave three consecutive correct responses), one form of the multiplication facts test was administered to the group. The target students were chosen because their baseline performances were the poorest in the class. However, because of the effectiveness of the instructional package, all students (including target students) in each group met the practice criterion simultaneously.

During administration of the multiplication facts test, all students were instructed to first find all the problems for which they knew strategies to use and complete those problems. Then they were to write answers for the remaining problems, giving their best try. They were reminded that they would receive reinforcement only if they correctly completed all the problems associated with each instructed strategy. The test problems involving only instructed strategies were corrected in the presence of students. The remaining uninstructed strategy problems were corrected when students were not present.

When all students received three consecutive multiplication facts test scores that were above baseline scores for the strategy being taught, instruction began on the next strategy. During pegword strategy instruction, a multiplication facts test was not administered until all 15 facts had been learned (after each student gave five consecutive correct responses for two consecutive sessions). When criterion was met for the pegword strategy (three consecutive multiplication facts test scores higher than baseline scores), the follow-up phase began.

Reinforcement of Performance

When treatment began, participants had to answer correctly all five multiplication facts test problems per strategy studied to receive reinforcement for that strategy. Problems involving the most recently taught strategy were scored and reinforced first, followed by previously taught strategies. When all five problems related to an instructed strategy were answered correctly, the teacher marked a "+5" by the corresponding letter in the lower right corner of the participant's test page, and five punches were made on his "credit card." If the participant correctly answered fewer than five problems related to the strategy currently being taught, he received no credit card punches. The punches were redeemable at the end of any session for items on a reinforcer menu in the classroom or were accumulated. For example, five punches would purchase a pencil, 15 punches would purchase a notebook, and 30 punches would buy a new box of crayons. The use of the token punch card and tangible items was a routine part of the classroom and was used for all students.

Follow-Up

Follow-up tests were administered for learned multiplication facts as new categories of multiplication facts were being introduced. Probes using the multiplication facts tests were administered daily until participants demonstrated consistent performance or until the end of the school year.

RESULTS

Tom

Tom's performance on the multiplication facts tests is presented in Figure 2. A comparison of Tom's baseline scores across all six categories of multiplication facts indicated that his scores were stable and the accuracy of his responses across baseline sessions ranged from 0% to 13% (mean of 5% accuracy). Substantial improvement in performance occurred with training, with his accuracy ranging from 47% to 100%. His mean accuracy was 87%. Continued improvement occurred during follow-up. His accuracy of responding during follow-up

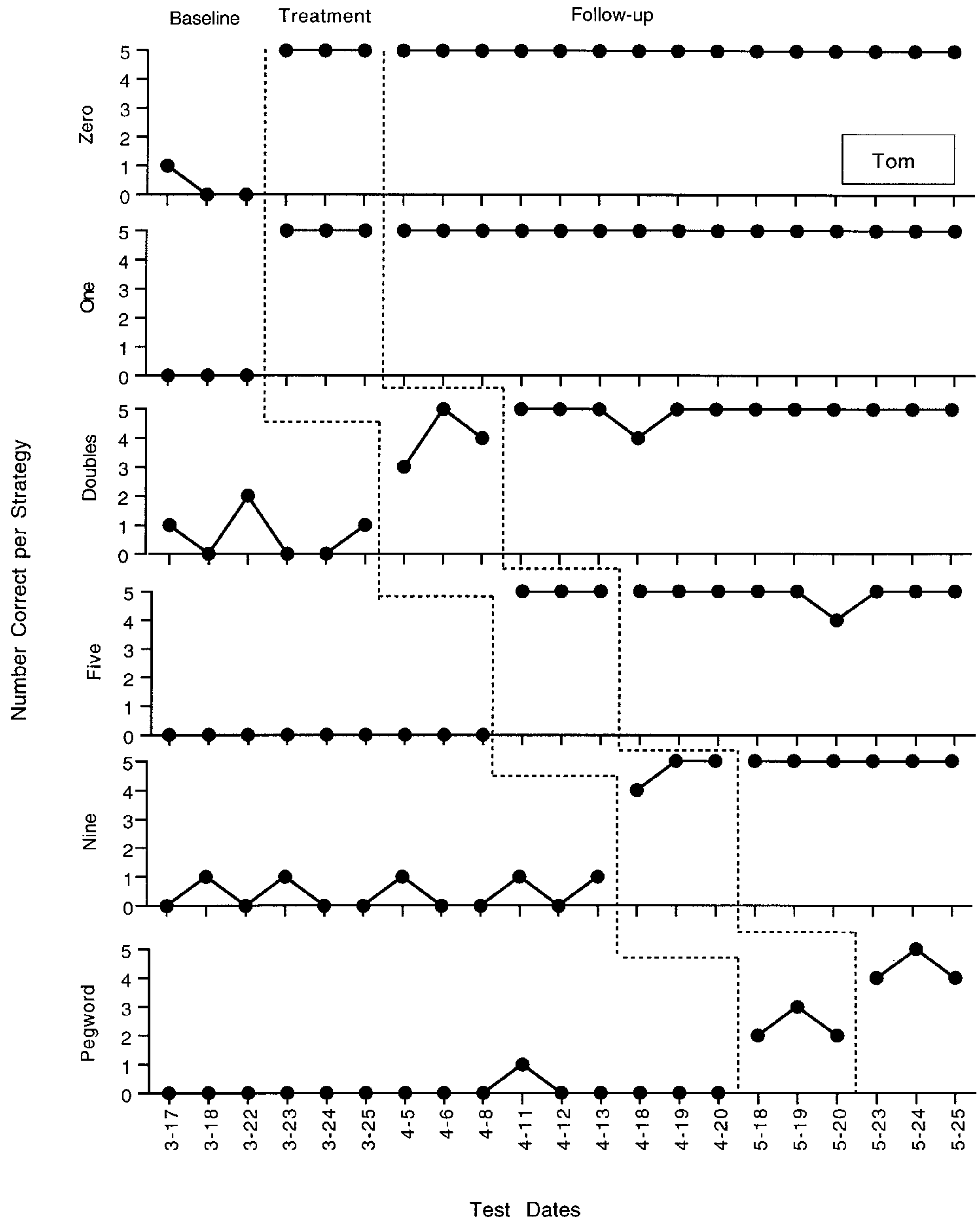

Figure 2. Tom's results on the multiplication facts tests.

ranged from 87% to 100%, with a mean of 97% accuracy.

Tom's results suggested that the instructional package was effective across all strategies. Instruction in the zeros, ones, and fives strategies produced immediate improvement to errorless performance. The doubles and nines strategies were only slightly less immediate, in that performance was errorless during most of follow-up. The results obtained during the pegword strategy were less rapid and did not result in errorless performance. However, he demonstrated an improving trend across sessions, with a 40% improvement from baseline to treatment and another 40% increase from treatment to follow-up. No generalization appeared to occur across strategies; improvement occurred only with training and not with practice.

Craig

Craig's performance is depicted in Figure 3. A comparison of Craig's baseline scores across all six categories of multiplication facts indicated that his scores were stable, with his accuracy ranging from 0% to 10% (mean of 4% accuracy). Substantial improvement in performance occurred with training, with his accuracy ranging from 53% to 100%. His mean accuracy was 91%. Continued improvement occurred during follow-up. His accuracy of responses during follow-up ranged from 80% to 100%, with a mean of 97%.

Instruction in the zeros, doubles, fives, and nines strategies produced immediate improvement to errorless performance and almost errorless performance following instruction in the one strategy. The results obtained during the pegword strategy were less rapid but demonstrated an improving trend across sessions, with 80% accuracy achieved during treatment and 100% accuracy achieved during follow-up. No generalization appeared to occur across strategies.

Damien

Damien's performance is depicted in Figure 4. A comparison of Damien's baseline scores across all six categories of multiplication facts indicated that his scores were stable and the accuracy of his responses ranged from 0% to 13% (mean of 4% accuracy). Substantial improvement in performance occurred with training, with his accuracy ranging from 80% to 100% (mean accuracy of 93%). Continued improvement occurred during follow-up. His accuracy of responses during follow-up ranged from 98% to 100%, with a mean of over 99%.

Instruction in the zeros, ones, doubles, and nines strategies produced immediate improvement to errorless performance. The results obtained during the fives and pegword strategies were only slightly less rapid but demonstrated improvement across sessions, with 100% accuracy achieved during treatment. No generalization appeared to occur across strategies.

DISCUSSION

Overall, the 3 participants responded in a remarkably similar fashion to the instructional package presented in their respective instructional groups. After instruction was received, a participant's accuracy was often 100%, and this was maintained during follow-up probes throughout the evaluation even as other strategies were introduced. Comparable results occurred across students, showing replication of the effects of the instructional package. The weakest effects occurred for the pegword strategy, with only Damien achieving the 100% mastery criterion in the pegword strategy during treatment. However, Craig and Tom attained 100% mastery once each during follow-up, with an overall performance substantially higher than any time during baseline. Only three follow-up tests were administered for pegwords because it was the last strategy taught.

Two additional aspects of the participants' behavior are of interest. First, no generalization occurred to untrained multiplication facts prior to instruction. This result suggests that behavior was responsive to the strategy trained and not to a general increase in multiplication fact skills. Second, performance continued to improve across sessions throughout training and follow-up. This re-

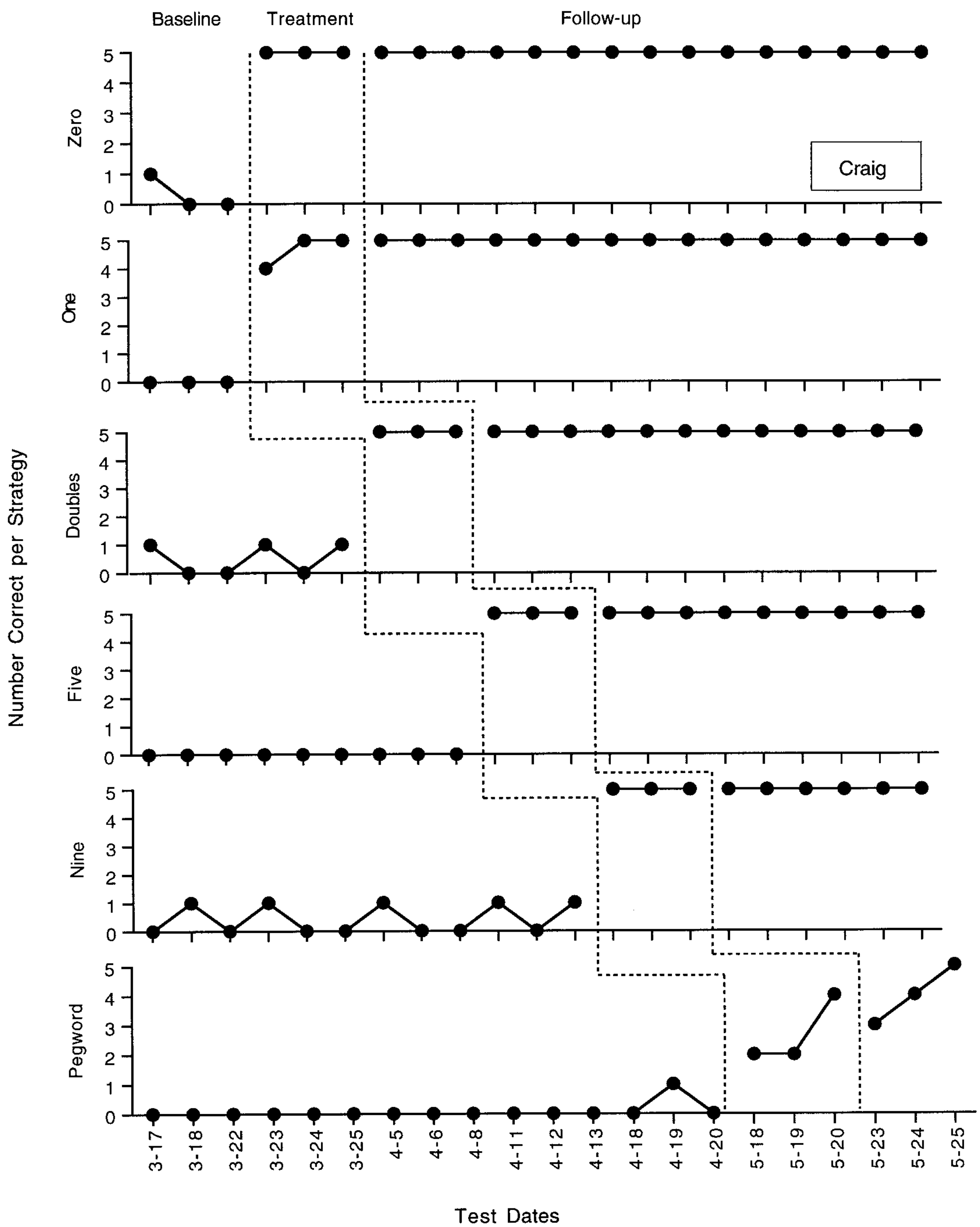

Figure 3. Craig's results on the multiplication facts tests.

sult suggests that continued practice with each strategy resulted in ongoing improvement. Both results suggest that the strategies trained were, in Stokes and Baer's (1977) terms, mediational. Thus, just as self-instructions can serve to guide ongoing performance for other topographies of behavior, the use of self-instruction regarding the use of strategies may aid students in their performance of difficult academic tasks.

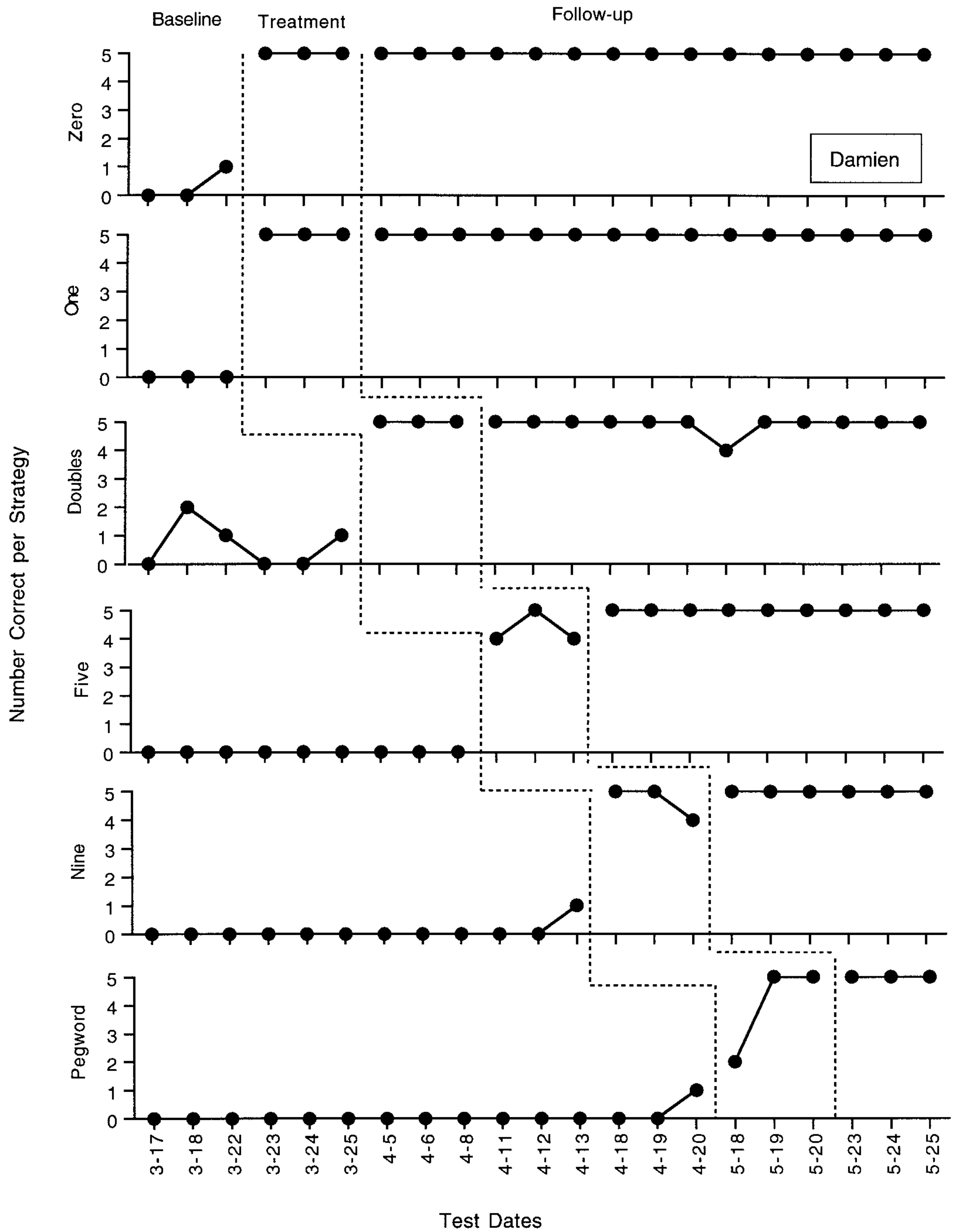

Figure 4. Damien's results on the multiplication facts tests.

Although we did not evaluate the sequence in which strategies were introduced, it appeared to enable the students to achieve rapid success on the multiplication facts tests, allowing for immediate reinforcement after test completion. The zeros and ones strategies were mastered almost immediately by all students, increasing opportunities for reinforcement with little effort needed by the students. This increase in reinforcement with minimal increases in effort may have resulted in an overall increase in the students' motivation to complete the multiplication facts tests as accurately as possible. The doubles, fives, and nines strategies required the participants to invest a little more effort, but these strategies were mastered with relative ease. Within the short time required to master the first five strategies, the participants were scoring 25 of 30 on nearly every test probe. By the time instruction occurred for the pegword strategy, each participant had experienced success with the package and was perhaps more willing to invest the effort to practice the most complicated strategy.

Participants appeared to be more enthused about math instruction throughout the implementation of the instructional package, compared to baseline. This increased enthusiasm was demonstrated by comments from students that they preferred this approach to learning multiplication facts. Further, students no longer avoided their independent math work. Math assignments involving multiplication were completed quickly and often chosen first, with few or no negative comments. Mastropieri and Scruggs (1989, 1991) also reported that students preferred mnemonic instructional methods and materials over conventional methods and materials. Students not only reported enjoying the instruction more but also attributed their learning successes directly to the mnemonic methods and materials. Student preference is an important factor because students are not as likely to exhibit effort over time with strategies that they do not like or do not feel are helpful.

During administration of the baseline probes, a common sentiment communicated to the teacher by the participants was that they were unable to solve the problems because they did not "know" their facts. In essence, they appeared to be communicating that they had been unable to memorize their facts. Rote memorization, which had previously been unsuccessful, appeared to be the only approach they had for solving basic multiplication facts. As instruction progressed, the participants may have learned that the solution of problems was not solely dependent on memorization but was also dependent on the strategies they had learned. In addition, although each student had documented memory deficits, it is not clear that the use of mnemonics is useful only with this subgroup of students. Perhaps mnemonics increased the students' preference for the tasks, which increased their motivation. The underlying mechanisms for why instructional strategies such as mnemonics are effective need to be evaluated.

The immediacy of improved performance replicates the previous work of McComas, Wacker, Cooper, et al. (1996) and McComas, Wacker, and Cooper (1996). In all three studies, academic behavior improved immediately and, in the cases studied, remained stable over time after initial improvement was achieved. These findings occurred across a wide range of academic tasks, instructional strategies, and age ranges of participants. When considered together, these results suggest that matching instructional strategies to student needs can be a highly effective approach to intervention and warrants further evaluation.

Finally, the instruction in this investigation was provided as part of a small group and was integrated into the typical program in the special education classroom. No external investigators were present in the classroom during this investigation. Thus, the social validity of this instructional approach was enhanced.

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STUDY QUESTIONS

1. How are students with learning disabilities usually taught multiplication facts? What alternative approach do the authors suggest?

2. How are mnemonics typically defined? How do the authors characterize mnemonics in operant terms? Finally, how are mnemonics related to Skinner's concept of "precurrent" behavior?

3. What specific behaviors was the instructional package designed to teach?

4. What were the specific strategies used? Describe the pegword strategy and use it to construct a mnemonic for the problem "3 × 7."

5. Describe how the authors assessed performance and the criterion they used for advancing a student from one strategy to the next.

6. Why did the authors use a multiple baseline design to assess the effects of intervention?

7. Describe the general pattern of results obtained.

8. What facilitative effect might the sequencing of strategies have had on performance?

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